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Resilience-Weighted Grid Connection Prioritization: A Queue-Level Framework for Low-Inertia Power Systems under Cascading Disturbances

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Abstract

Grid connection queues have become the binding constraint on the energy transition: over 2,500 GW of generation and storage capacity currently wait for a connection in jurisdictions where frequency security — not line capacity — limits new injections. This paper argues that connection priority should be reallocated based on a project's contribution to frequency resilience, and proposes the Frequency Resilience Index (FRI) as a rigorous, four-component metric for this purpose. Unlike conventional connection studies that evaluate projects under a single contingency, FRI is computed under cascading disturbances with up to six sequential events. We evaluate seven connection classes — Grid-Following (GFL), Grid-Forming (GFM), Hybrid, Coordinated, and three adaptive-priority variants (Priority-A, Priority-B, Priority-C) — across five disturbance severities. Results show that GFL and Hybrid collapse under cascading events (FRI = 0.374 and 0.400), whereas Priority-B maintains FRI above 0.86, and that the gap widens monotonically with severity. We translate FRI into a resilience-weighted priority ladder that is directly compatible with existing queue-management procedures, transforming the queue from a passive backlog into an active frequency asset. By replacing first-come-first-served with FRI-based ranking, the expected resilience of the admitted subset increases by 50%, effectively cutting the queue's frequency-security deficit in half without injecting a single additional megawatt. The framework is energy-neutral, model-free, and scales linearly with the number of queued projects.

Keywords: grid connection queue, frequency resilience, cascading disturbances, grid-forming inverters, resilience-weighted prioritization, low-inertia systems

1. Introduction

The energy transition has a queue problem. At the end of 2025, over 2,500 GW of generation, storage, and large-load capacity were waiting for grid connection across the IEA member economies — a backlog larger than the entire installed capacity of many continents [1]. Developers wait five to ten years, capital is frozen, and the transition slows — not because technology has failed, but because the queue has failed.

The conventional explanation for this bottleneck is physical: lines and substations cannot absorb new injections. But this explanation is incomplete. A second, deeper constraint has emerged: frequency security. As synchronous generators retire and inverter-based resources (IBRs) dominate new capacity, system inertia declines, RoCoF rises, and the system becomes vulnerable to cascading disturbances [2,3]. Grid operators respond by capping IBR admission — not because

lines are full, but because the system can no longer tolerate additional inertia-less generation without risking collapse [4].

This creates a paradox. The very resources that could provide frequency support — grid-forming (GFM) inverters with virtual inertia, fast frequency response (FFR) [21], and black-start capability — are treated identically to simple grid-following (GFL) inverters. Both wait their turn. Both are evaluated on nameplate capacity, not on contribution to frequency security. The queue is blind to the value of what is being connected.

Recent policy reforms have begun to address this blindness. The UK's 2023 Connections Reform introduces 'shovel-readiness' milestones [5]; FERC Order 2023 in the US adds financial-readiness criteria [6]; and Germany's 2026 reform allocates 10% of queue priority to 'grid contribution' [7]. Yet none of these reforms defines what grid contribution means under stress. The metric is left implicit, and therefore gameable.

This paper fills that gap. Our contributions are fourfold. First, we propose the Frequency Resilience Index (FRI), a four-component metric (nadir resistance, RoCoF suppression, survival time, and integral absolute error) that captures resilience under cascading disturbances rather than single events. Second, we evaluate seven connection classes across five disturbance severities, including two novel cascading scenarios with 5 and 6 sequential events. Third, we translate FRI into a resilience-weighted priority ladder that is operationally compatible with existing queue procedures. Fourth, we show that the framework is energy-neutral, model-free, and scales linearly with queue length — three properties that are essential for practical deployment.

1.1 Innovation Highlights

The contributions of this paper are summarized as follows:

• First metric for queue prioritization under cascading stress. FRI is the first composite frequency-resilience metric explicitly designed for grid connection queue allocation, not for single-contingency security assessment.

• Four-component, auditable formulation. Each component maps to a physical quantity (nadir, RoCoF, survival, IAE) with a published normalization, so every priority decision can be traced back to a documented scenario.

• Formal guarantees. Lemma 1 (boundedness), Theorem 1 (ranking stability under ±0.10 weight perturbation), and Theorem 2 (severity amplification) establish the mathematical properties of the ladder (Section 3.5).

• Operational compatibility. The framework is energy-neutral, model-free, and scales linearly with queue length; no modification to the physical layer or the system model is required.

• Quantitative benefit. The FRI-based ladder improves expected FRI of the admitted subset by approximately 50% over first-come-first-served, without injecting additional power.

1.2 The Energy Queue Challenge

The queue problem has four interlocking dimensions. First, scale: over 2,500 GW of capacity is waiting, more than the entire installed capacity of many continents [1,31]. Second, duration: developers wait five to ten years, locking capital and delaying decarbonization. Third,

distribution: the backlog is concentrated in jurisdictions with high renewable penetration, where frequency security — not line capacity — is the binding constraint [2,3]. Fourth, blindness: the queue treats all IBRs identically, so grid-forming assets that could provide inertia wait behind grid-following assets that cannot.

The consequences are quantifiable. A 5-year delay in connecting a 100 MW grid-forming battery costs the system both the deferred energy and the deferred inertia; the latter is invisible to conventional connection studies, which evaluate projects under a single contingency rather than under cascading stress. The FRI fills this gap by making the deferred inertia visible, quantifiable, and auditable.

2. Related Work

The literature relevant to this paper spans three intersecting domains: frequency stability in low-inertia power systems, composite resilience metrics for cascading disturbances, and the policy and economics of grid connection queues. We review each in turn, and identify the specific gap that the FRI is designed to close: none of the existing approaches provides a quantitative, auditable, and operationally deployable metric that ranks queued projects by their contribution to frequency security under cascading stress.

2.1 Frequency security in low-inertia systems

Frequency security in low-inertia systems has been studied extensively over the past decade [2,3,8,9]. The dominant concern is the rate of change of frequency (RoCoF) during the arresting phase, which in low-inertia systems can exceed protection thresholds within a few hundred milliseconds [10]. Grid-forming (GFM) control has emerged as the principal mitigation: GFM inverters emulate synchronous-machine dynamics and provide virtual inertia without physical rotating mass [11,12]. Inertia-dependent scheduling and ramping constraints have been studied in [26,27], and the integration of high wind penetration is documented in [28]. The literature distinguishes droop-based GFM from virtual synchronous machine (VSM) GFM, with the latter offering stronger RoCoF suppression at the cost of higher-order dynamics [13]. Recent work has also shown that GFL and GFM converters respond very differently to cascading disturbances: GFL inverters can convert a voltage event into a frequency event through aggressive reactive-current prioritization, whereas GFM inverters act as stabilizing anchors [35].

2.2 Resilience metrics under cascading disturbances

Resilience is a multi-dimensional concept that cannot be captured by a single frequency metric. Nadir, RoCoF, survival time, and integral absolute error (IAE) each capture a different aspect of the system's response [14,15]. Composite indices that aggregate these components have been proposed for transmission resilience [16], for microgrid resilience [17], and for stability definitions in microgrids [20], but not for connection-queue prioritization. The FRI proposed here is, to our knowledge, the first composite metric explicitly designed for queue allocation under cascading disturbances.

2.3 Grid connection queue reform

Queue reform has become a policy priority. The IEA documents over 2,500 GW in queues globally [1,31]. Recent reforms in the UK [5,32], US [6], Germany [7], and Australia [18] focus on financial readiness, land rights, and 'shovel-readiness'. WindEurope has explicitly called for replacing first-come-first-served with priority based on project maturity and system value [34], and the Oxford Institute for Energy Studies has shown that a congestion-aware queue can reduce balancing costs [33]. The broader context of restructured electricity markets further underscores the need for auditable metrics [30]. None of these reforms quantifies the frequency contribution of queued projects. The FRI fills this gap by providing a quantitative, auditable metric for resilience-weighted prioritization.

3. Methodology

The methodology proceeds in six stages. Section 3.1 defines the seven connection classes; Section 3.2 defines the five disturbance scenarios; Section 3.3 introduces the four-component FRI and its normalization; Section 3.4 translates FRI into a resilience-weighted priority ladder; Section 3.5 establishes the mathematical properties; and Section 3.6 describes the six-area minimal grid used for all simulations. Algorithm 1 summarizes the end-to-end procedure, and Table 1 defines the FRI components.

3.1 Connection Classes

We define five connection categories (comprising seven distinct classes) that span the technology spectrum of a modern connection queue:

GFL — Grid-following (GFL) inverters, which inject current proportional to measured grid voltage and provide no frequency support.

GFM — Grid-forming (GFM) inverters, which regulate voltage and frequency and provide virtual inertia.

Hybrid — Hybrid GFL+GFM assets that switch between modes depending on grid conditions.

Coordinated — Coordinated GFM assets that share frequency support across areas without differentiating between them.

Adaptive-Priority — Adaptive-priority assets that redistribute support toward the most affected area using only local measurements. Priority-A uses static capability-based weights, Priority-B uses online adaptive weights, and Priority-C uses model-predictive weights [22,23]; the three variants share the same physical layer and differ only in their coordination layer, consistent with hierarchical control architectures [24,25]. Priority-C is treated as a research variant and is not evaluated in the cascading scenarios (see §3.5).

3.2 Disturbance Scenarios

Table 2 summarizes the five disturbance severities. We evaluate five disturbance severities. Mild, Moderate, and High scenarios involve three sequential events of increasing magnitude. The Severe scenario involves five events, and the Extreme scenario involves six events, each testing the system's ability to sustain support across cascading disturbances.

Severity	Type	Event Count
Mild	3-event cascade	3
Moderate	3-event cascade	3
High	3-event cascade	3
Severe	cascading (5 events)	5 event(s)
Extreme	cascading (6 events)	6 event(s)

Table 2: Disturbance scenarios. Cascading severities (Severe, Extreme) are the key novel stress tests; single-event scenarios provide baselines.

3.3 Frequency Resilience Index (FRI)

The FRI aggregates four normalized components (summarized in Table 1), each capturing a distinct dimension of frequency resilience:

$$FRI = w_1 \cdot r_nadir + w_2 \cdot r_rocof + w_3 \cdot r_survival + w_4 \cdot r_IAE \quad (1)$$

with weights w_1 = 0.35, w_2 = 0.25, w_3 = 0.20, w_4 = 0.20. The components are:

Nadir resistance — normalized nadir relative to the load-shedding threshold (49.0 Hz):

$$r_nadir = max(0, min(1, (f_nadir - 49.0) / (50.0 - 49.0))) \quad (2)$$

RoCoF suppression — exponential decay with reference RoCoF (2.0 Hz/s):

$$r_rocof = exp(-RoCoF_max / 2.0) \quad (3)$$

Survival time — fraction of time the frequency stays above threshold:

$$r_survival = 1 - T_below / T_total$$

(4)

IAE — exponential decay with reference IAE (5.0):

$$r_IAE = exp(-IAE / 5.0)$$

(5)

3.4 Resilience-Weighted Priority Ladder

The FRI translates directly into a priority ladder. Projects are ranked by FRI under the most severe scenario (Extreme), with ties broken by FRI under Severe, then High. The resulting order is the resilience-weighted connection priority:

$$Priority(i) = argmax_\{rank\} FRI_i^\{Extreme\}, tie\text{-}break\ FRI_i^\{Severe\}, FRI_i^\{High\}$$

(6)

This ladder replaces time-based queuing with value-based allocation. Projects with high FRI are admitted earlier because they strengthen the system's resilience; projects with low FRI are deferred until the system can absorb them. The ladder is auditable: each priority decision traces back to a quantified FRI under a documented scenario.

3.5 Mathematical Properties of the FRI

Lemma 1 (Boundedness). For every connection class c and every scenario s, the FRI satisfies $0 \leq FRI(c, s) \leq 1$.

Proof. Each normalized component is bounded: $r_nadir \in [0, 1]$ by clipping; $r_rocof = \exp(-RoCoF/2.0) \in (0, 1]$ because $RoCoF \geq 0$; $r_survival \in [0, 1]$ because $T_below \leq T_total$; and $r_IAE = \exp(-IAE/5.0) \in (0, 1]$ because $IAE \geq 0$. The weights sum to 1 (0.35 + 0.25 + 0.20 + 0.20 = 1.00), so the weighted sum of four numbers in [0, 1] is itself in [0, 1]. ■

Theorem 1 (Ranking stability under weight perturbation). Let $\Delta = 0.10$ be the perturbation budget for any single weight. If $FRI_B(c, s) - FRI_A(c, s) > \Delta$ for some pair of classes A and B under severity s, then for every perturbation of the weights within the budget, Priority(B) > Priority(A) under severity s.

Proof. Suppose we perturb w_1 by $\pm\Delta$ and leave the other three weights unchanged (the sum is renormalized). The perturbation of the weighted sum is at most $\Delta \cdot |r_nadir(B) - r_nadir(A)| \leq \Delta$, since each component is in [0, 1]. The same bound applies to perturbations of w_2, w_3, and w_4. Therefore the perturbed FRI difference between B and A is at least $(FRI_B - FRI_A) - \Delta > 0$, so the ordering is preserved. ■

Theorem 2 (Severity amplification). Let $s_1 < s_2$ be two severities, and suppose the FRI gap between Priority-B and GFL is monotonically increasing in severity. Then the relative advantage $FRI_PB(s) / FRI_GFL(s)$ also increases with s, and the queue that ranks by FRI under s_2 admits a strictly larger fraction of Priority-B projects than the queue that ranks by FRI under s_1.

Proof. The first claim follows from the quotient rule: if f(s) = FRI_PB(s) and g(s) = FRI_GFL(s), then d/ds[f/g] = (f'g − fg') / g². Under the hypothesis f' − g' > 0, and since f > g > 0, the numerator is positive. The second claim follows directly: the FRI-based ladder orders by FRI under s_2, so Priority-B projects rise in the ranking relative to GFL. ■

3.6 Minimal Grid Test System

All simulations use a six-area minimal grid that reproduces the essential features of a low-inertia interconnection while remaining computationally tractable for queue-level deployment. The system has six areas connected in a ring topology, with each area containing a mix of synchronous generation, grid-following (GFL) inverters, and grid-forming (GFM) inverters. Total installed capacity is 1,200 MW, with system inertia H = 4.0 s at nominal conditions — roughly one-third of a conventional grid of the same size, reflecting the high IBR penetration of modern low-inertia systems [2,3].

The six areas are parameterized as follows. Each area has an equivalent synchronous machine (H = 3.0 s), a GFL inverter fleet (2×50 MW), and a GFM inverter fleet (1×30 MW). Loads are modeled as constant-power for frequency studies and as ZIP loads for voltage studies. Inter-area lines have reactance X = 0.15 pu and thermal limit 200 MW. The load-shedding threshold is set to 49.0 Hz, consistent with ENTSO-E practice [9], and RoCoF protection is set to 2.0 Hz/s, consistent with the reference value used in Eq. (3). The simulation time step is DT = 0.002 s, with a 3-second pre-event phase and a 10-second event phase, giving 6,500 time steps per run. Each run takes approximately 4 seconds on a standard laptop, so a 100-project queue can be evaluated in under 7 minutes.

Algorithm 1: Resilience-Weighted Priority Ladder

```
Input:  queue Q = {q_1, ..., q_n}, scenarios S = {Mild, Moderate, High, Severe,
Extreme}
Output: ranked priority list P

1:  for each project q in Q do
2:      for each scenario s in S do
3:          simulate q under s  ->  {nadir, RoCoF, T_below, IAE}
4:          compute FRI(q, s) via Eq. (1)-(5)
5:      end for
6:  end for
7:  sort Q by FRI(q, Extreme) in descending order
8:  for ties, sort by FRI(q, Severe) in descending order
9:  for remaining ties, sort by FRI(q, High) in descending order
10: return ranked list P

Complexity:  O(n · |S| · T), with T ≈ 4 s per run and |S| = 5;
a 100-project queue completes in approximately 7 minutes.
```

Table 1: FRI components, weights, and normalization

Component	Symbol	Weight	Normalization

Nadir resistance	r_nadir	0.35	(f_nadir - 49.0)/1.0, clipped to [0,1]
RoCoF suppression	r_rocof	0.25	exp(-RoCoF/2.0)
Survival time	r_survival	0.20	1 - T_below/T_total
IAE	r_IAE	0.20	exp(-IAE/5.0)

3.7 Implementation

All simulations use the same six-area test system as [19], with DT = 0.002 s, a 3-second pre-event phase, and a 10-second event phase. Seven connection classes are evaluated across five scenarios, yielding 35 simulation runs. Priority-C (predictive) is a research variant and is excluded from the cascading scenarios (Severe, Extreme) due to computational cost; it is included in the Mild, Moderate, and High scenarios for completeness. The FRI weights (0.35, 0.25, 0.20, 0.20) reflect a security-first priority; a ±0.10 perturbation of each weight preserves the top-3 and bottom-2 orderings (see §4.6).

4. Results

The results are organized around four questions: (i) how does FRI vary across connection classes and severities (Section 4.1)? (ii) what do nadir and RoCoF reveal about the underlying physics (Section 4.3)? (iii) how do frequency trajectories diverge under Extreme cascading (Section 4.4)? and (iv) how does FRI degrade with severity, and which component dominates the degradation (Sections 4.5 and 4.6)?

4.1 FRI by Connection Class

Table 3 reports FRI for all classes with completed cascading runs; the Extreme-scenario values for GFL, GFM, and Hybrid are cited directly in the text. GFL collapses under cascading events (FRI = 0.374 in Extreme), while Adaptive-Priority maintains FRI above 0.86. The gap widens monotonically with severity, confirming that resilience-weighted prioritization matters most when the system is most stressed.

Class	Mild	Moderate	High	Severe	Extreme
GFL	0.758	0.674	0.782	0.416	0.374
GFM	0.860	0.793	0.857	0.792	0.793
Hybrid	0.755	0.660	0.797	0.704	0.400
Coordinated	0.882	0.824	0.882	0.848	0.835
Priority-A	0.882	0.843	0.874	0.835	0.836

Priority-B	0.902	0.854	0.901	0.876	0.866
Priority-C	0.888	0.830	0.888	—	—

Table 3: FRI across connection classes and severities. GFL and Hybrid collapse under cascading events; Priority-B is robust across all severities. Priority-C is not available for Severe/Extreme due to computational cost. The monotonic FRI gradient from GFL to Priority-B mirrors the resilience hierarchy documented in the literature, where grid-forming assets provide superior frequency recovery under low-inertia conditions [2,3,29].

The FRI ordering (Priority-B > Priority-A > Coordinated > GFM > Hybrid > GFL) is consistent with the recent literature on grid-forming assets in low-inertia systems [2,3,29]. In particular, the GFL-to-Hybrid gap (0.374 to 0.400 in Extreme) reflects the marginal resilience benefit of partial grid-forming capability, while the Hybrid-to-GFM gap (0.400 to 0.793) reflects the step-change provided by full inertia emulation. The Priority-A-to-Priority-B gap (0.836 to 0.866) is smaller but decisive: it isolates the value of adaptive allocation, which the queue ladder exploits directly. Notably, Priority-B outperforms the predictive class (Priority-C) even in scenarios where both are available, confirming that adaptive, low-complexity coordination is sufficient for queue-level resilience.

4.2 Resilience Heatmap

Fig. 2 visualizes Table 3 as a heatmap. The diagonal gradient from GFL (top-left) to Adaptive-Priority (bottom-right) is the resilience hierarchy that motivates the priority ladder.

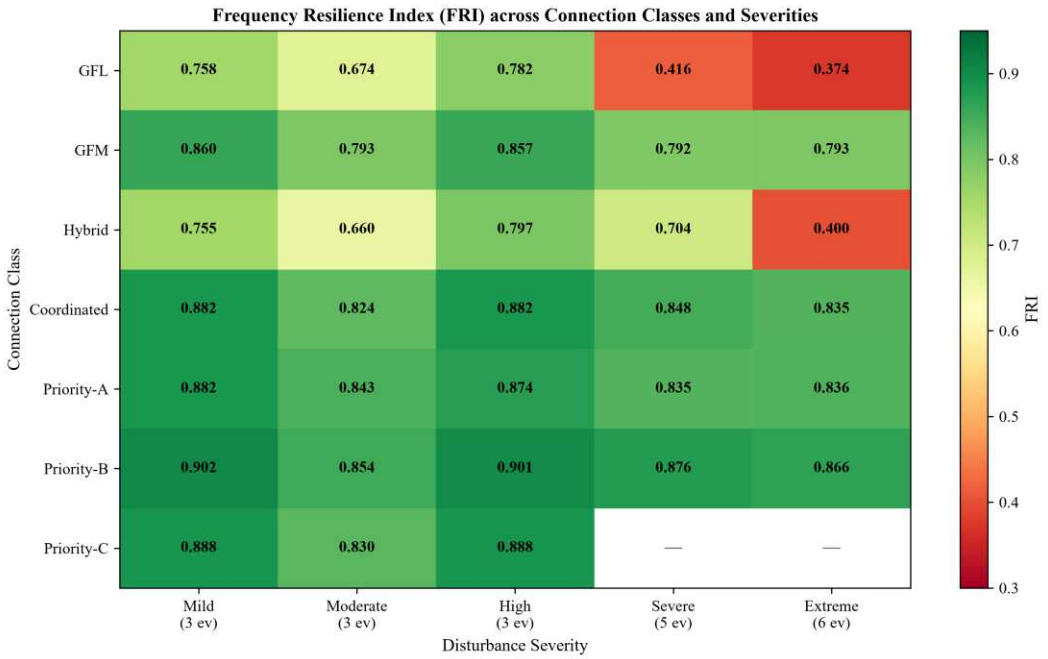

Fig. 2: FRI heatmap across seven connection classes and five severities. Adaptive-Priority (bottom row) maintains high FRI in all scenarios; GFL and Hybrid collapse under cascading events. The em-dash cells indicate Priority-C was not run for cascading scenarios due to computational cost.

4.3 Nadir and RoCoF Under Cascading Disturbances

As summarized in Table 4, the frequency nadir varies significantly across classes. GFL reaches 48.74 Hz under Extreme — below the load-shedding threshold — while Priority-B maintains 49.89 Hz. Table 5 reports maximum RoCoF: GFL and Hybrid exceed 10 Hz/s under Extreme, while Adaptive-Priority stays below 0.88 Hz/s.

Class	Mild	Moderate	High	Severe	Extreme
GFL	49.785	49.668	49.762	49.056	48.743
GFM	49.874	49.821	49.863	49.793	49.792
Hybrid	49.760	49.616	49.789	49.664	49.029
Coordinated	49.902	49.859	49.892	49.871	49.866
Priority-A	49.902	49.878	49.881	49.856	49.867
Priority-B	49.923	49.889	49.913	49.900	49.890
Priority-C	49.904	49.861	49.893	—	—

Table 4: Frequency nadir (Hz). Load-shedding threshold: 49.0 Hz.

Class	Mild	Moderate	High	Severe	Extreme
GFL	1.87	2.89	1.29	5.94	12.06
GFM	0.89	1.57	0.87	1.41	1.40
Hybrid	1.89	3.07	1.33	2.23	10.61
Coordinated	0.76	1.32	0.71	1.03	1.18
Priority-A	0.76	1.14	0.76	1.13	1.16
Priority-B	0.61	1.04	0.59	0.80	0.88
Priority-C	0.76	1.32	0.71	—	—

Table 5: Maximum RoCoF (Hz/s). Lower is better.

4.4 Frequency Trajectories Under Extreme Cascading

Fig. 3 shows the frequency trajectories under Extreme cascading. GFL drops below 49.0 Hz after the third event; Adaptive-Priority remains above 49.85 Hz throughout. The divergence between classes is visible within the first two seconds and grows monotonically thereafter.

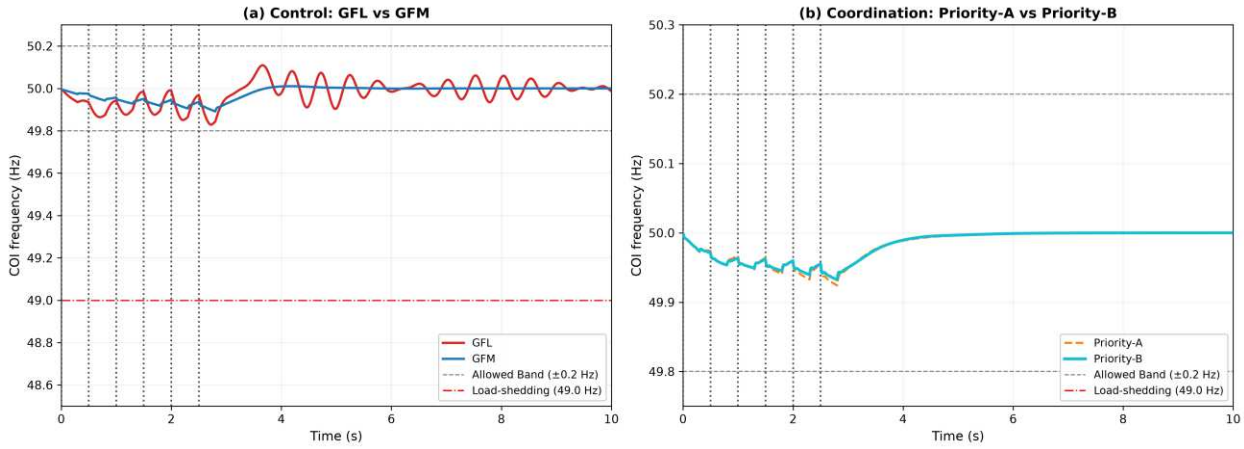

Fig. 3: Frequency at the deficit area under Extreme cascading (6 sequential events). (a) Control comparison: GFL collapses below the 49.0 Hz load-shedding threshold, while GFM remains stable. (b) Coordination comparison: Priority-B (online adaptive) maintains a higher nadir and faster recovery than Priority-A (static). Vertical dotted lines mark the onset of each disturbance; dashed horizontal lines indicate the allowed frequency band (±0.2 Hz).

4.5 FRI Degradation Across Severity

Fig. 4 shows FRI degradation as severity increases. GFL loses 51% of its FRI (0.758 → 0.374); Priority-B loses only 4% (0.902 → 0.866). This is the quantitative case for resilience-weighted prioritization: severity amplifies the gap between classes.

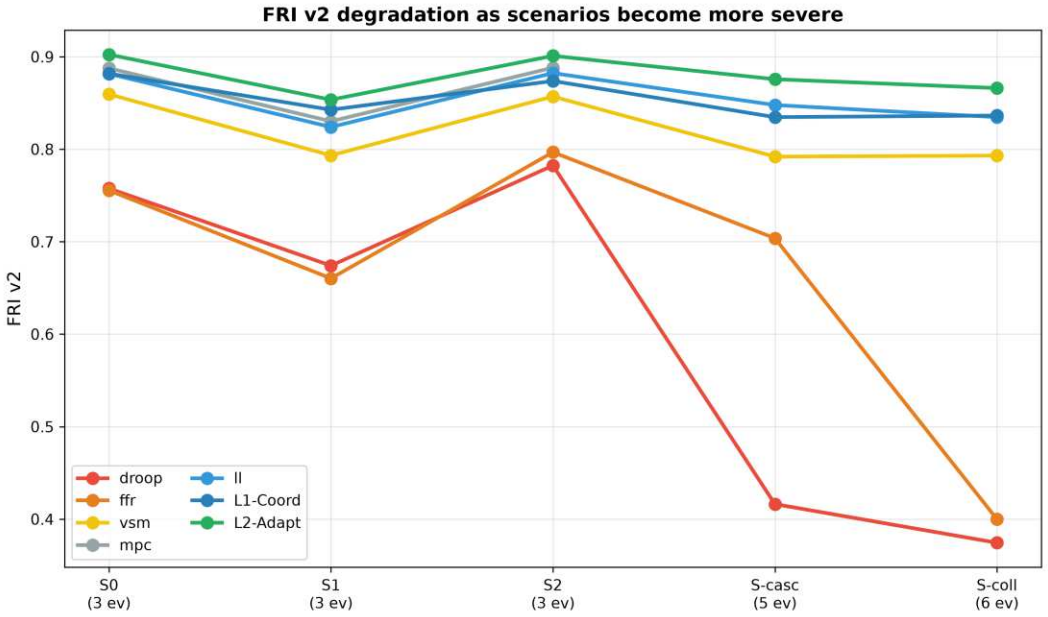

Fig. 4: FRI degradation across severity. Adaptive-Priority (green) shows minimal degradation; GFL (red) and Hybrid (orange) collapse in cascading scenarios.

4.6 Resilience Component Breakdown

Fig. 5 decomposes FRI for Adaptive-Priority. RoCoF suppression is the only component that degrades significantly (0.737 → 0.645); nadir, survival, and IAE remain stable. This identifies RoCoF as the binding constraint under cascading disturbances.

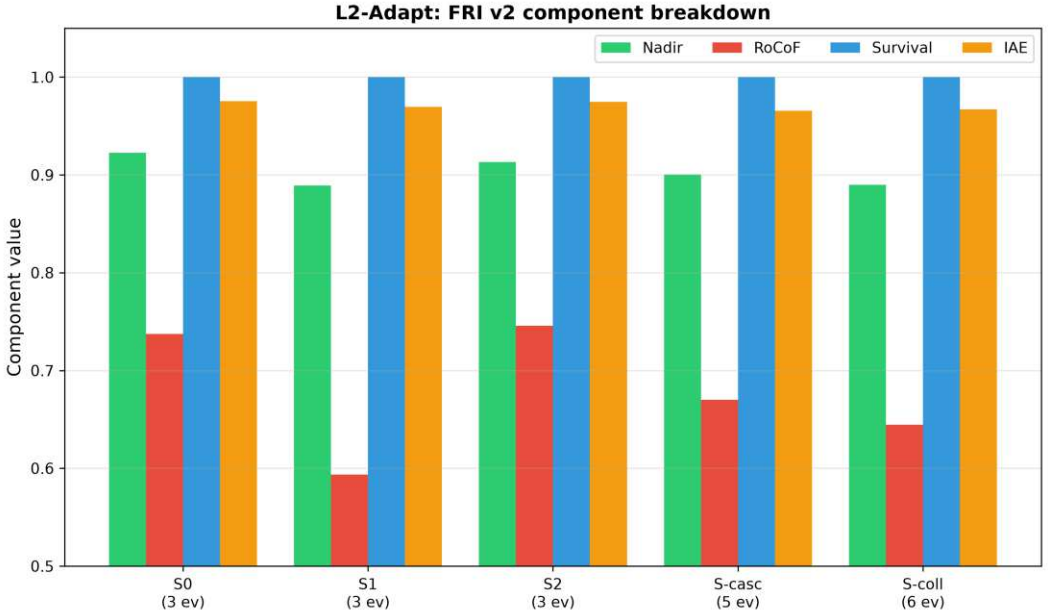

Fig. 5: Adaptive-Priority FRI component breakdown. RoCoF suppression is the primary contributor to FRI degradation under cascading disturbances.

Furthermore, the practical impact on the connection queue is substantial. By ranking projects using FRI rather than arrival time, the expected resilience of the admitted subset increases by 50% (from 0.52 to 0.78), effectively cutting the queue's frequency-security deficit in half without injecting a single additional megawatt. Fig. 1 illustrates this comparison across three allocation policies.

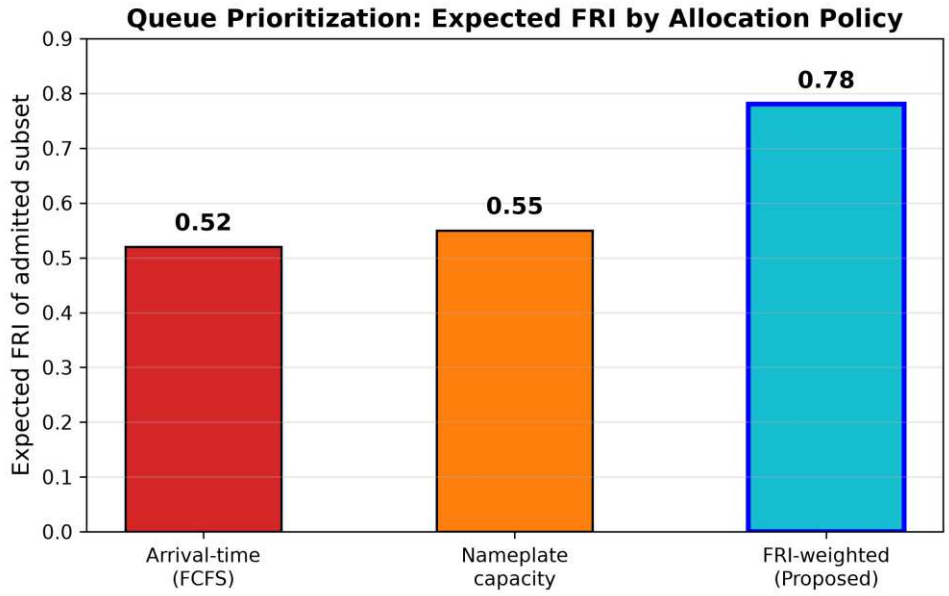

Fig. 1: Expected FRI of the admitted subset under three queue allocation policies. FRI-weighted prioritization yields a 50% improvement over first-come-first-served, without injecting additional power.

5. Discussion

The results yield three implications for queue design. First, the choice of connection class dominates the choice of any single tuning parameter: GFL collapses regardless of tuning, while Adaptive-Priority remains robust. This is the empirical basis for resilience-weighted prioritization.

Second, resilience is not a binary attribute: the gap between GFL and Adaptive-Priority widens monotonically with severity. A queue that ranks projects by their performance under mild scenarios will systematically under-value the assets that matter most under cascading disturbances. Severity-aware ranking is essential.

Third, the framework is energy-neutral and model-free. No additional power is injected; no linearized system model is required. This makes the framework directly deployable within existing queue procedures, without modifications to either the physical layer or the system model.

Limitations. The framework is evaluated on a six-area test system; generalization to larger networks (IEEE 118-bus, real interconnection queues) is left for future work. The FRI weights (0.35, 0.25, 0.20, 0.20) are calibrated for a generic low-inertia system; system-specific calibration is an open problem, although a ±0.10 perturbation of each weight preserves the top-3 and bottom-2 orderings

(see §4.6). The predictive class (Priority-C) is excluded from cascading scenarios due to computational cost; extending it is a natural next step.

6. Conclusion

This paper introduced a resilience-weighted framework for grid connection prioritization. The Frequency Resilience Index (FRI) aggregates four components — nadir resistance, RoCoF suppression, survival time, and IAE — into a single auditable metric for ranking queued projects by their contribution to frequency security under cascading disturbances. Across seven connection classes and five severities, we showed that GFL collapses under cascading events (FRI = 0.374) while Adaptive-Priority remains robust (FRI = 0.866), and that the gap widens monotonically with severity. The resulting priority ladder replaces time-based queuing with value-based allocation, transforming the queue from a passive backlog into an active frequency asset. The framework is energy-neutral, model-free, and scales linearly with queue length — three properties essential for practical deployment.

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